



HAM It Up!

An Amateur Radio Overview

A Digital Learning Network Experience



Designed To Share

NASA Space Exploration

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An Amateur Radio Overview

A Digital Learning Network Experience



**National Aeronautics and
Space Administration**

Designed To Share

The Vision for Space Exploration

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Digital Learning Network (DLN) Expedition

A DLN Expedition is a one time connection that allows students to experience NASA first-hand. Each expedition features an integrated educational package of grade-appropriate instruction and activities centered on a 50 minute videoconference. Students participate in a Question and Answer session with a NASA JSC education specialist or a NASA Subject Matter Expert.

SEQUENCE OF EVENTS

Pre-Conference Requirements

Online Pre-assessment A pre-assessment tool is available to determine the students' level of understanding prior to the videoconference. Suggested answers are included.

Expedition Videoconference

Expedition Videoconference (About 45-60 minute conference)

Join the Digital Learning Network as we explore how astronauts on the International Space Station communicate using amateur, or HAM, Radio. Learn how amateur radio works, its purpose on the International Space Station, and how educators and students can participate in radio downlink events with astronauts through ARISS.

Post-Conference Requirements

Online Post-assessment

A post-assessment tool is available to determine changes in student levels of understanding.

NASA Education Evaluation Information System (NEEIS) Feedback Forms

Educator and student feedback forms are available online for all DLN events.



Expedition Overview

Grade Level 9-12

Focus Question

Communication is an essential component of a manned NASA mission. It is important for astronauts to stay in contact with Mission Control. One way astronauts keep in touch on the International Space Station is with amateur radio, or HAM radio. This method is also a means for the public to communicate with astronauts on board the Station. How does HAM radio work? How can educators and students participate in HAM radio connections?

Instructional Objectives

Students will:

- Understand the function and importance of amateur radio on the International Space Station through the videoconference event;
- Identify resources available for radio downlink participation through the videoconference event;
- Construct a diagram of the electromagnetic spectrum in pre- and post-activities;
- Identify the components of a radio wave in pre- and post-activities;
- Calculate frequency and wavelength in pre- and post-activities.

National Standards

National Science Education Standards (NSES)

Unifying Concepts

Content Standard A – Science as Inquiry

Content Standard B – Physical Science

Content Standard E – Science and Technology

National Council of Teachers of Mathematics (NCTM)

Content Standard – Algebra

Understand patterns, relationships and functions

Represent and analyze mathematical situations and structures using algebraic symbols

International Technology Education Association (ITEA)

Standard 2 – Core Concepts of Technology

Standard 3 – Relationships Among Technologies and the Connections Between Technology and other Fields

Standard 17 – Information and Communication Technologies



National Standards

National Science Education Standards (NSES) (from www.nap.edu)

<i>Science</i>	Radio Waves	DLN Connection	Waves
Unifying Concepts Evidence, models, and explanations	X	X	X
Content Standard A: Science as Inquiry Abilities Necessary to do Scientific Inquiry		X	
Content Standard B: Physical Science Structure and Properties of Matter	X	X	X
Motion and Forces	X	X	X
Content Standard E: Science and Technology Abilities of Technological Design		X	
Understanding about Science and Technology		X	

Expected Student Behaviors

Unifying Concepts

Evidence, models, and explanations – *At the upper grades, the standard should facilitate and enhance the learning of scientific concepts and principles by providing students with a big picture of scientific ideas--for example, how measurement is important in all scientific endeavors.*

Content Standard A – Science as Inquiry

Abilities Necessary to do Scientific Inquiry – *In grades 9-12, students should develop sophistication in their abilities and understanding of scientific inquiry. Students can understand that experiments are guided by concepts and are performed to test ideas.*

Content Standard B – Physical Science

Structure and Properties of Matter – *Students should formulate an understanding of the microstructure of matter, which can be supported by laboratory experiences with the macroscopic and microscopic world of forces, motion (including vibrations and waves), light, and electricity.*

Motion and Forces – *Students should develop an understanding that electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.*

Content Standard E – Science and Technology

Abilities of technological design – *Students can understand and use the design model outlined in this standard. Students respond positively to the concrete, practical, outcome orientation of design problems before they are able to engage in the abstract, theoretical nature of many scientific inquiries.*

Understanding about Science and Technology – *In general, high school students do not distinguish between the roles of science and technology. Helping them do so is implied by this standard. This lack of distinction between science and technology is further confused by students' positive perceptions of science, as when they associate it with medical research and use the common phrase "scientific progress." However, their association of technology is often with environmental problems and another common phrase, "technological problems."*

National Council of Teachers of Mathematics (NCTM)(from standards.nctm.org)

<i>Mathematics</i>	Radio Waves	DLN Connection	Waves
<u>Algebra</u> Understand patterns, relationships, and functions (see <i>student behaviors for benchmarks</i>)	X	X	
Represent and analyze mathematical situations and structures using algebraic symbols (see <i>student behaviors for benchmarks</i>)	X	X	

Expected Student Behaviors

Content Standard – Algebra

Understand patterns, relationships and functions

Students should:

- *understand relations and functions and select, convert flexibly among, and use various representations for them*
- *understand and perform transformations such as arithmetically combining, composing, and inverting commonly used functions, using technology to perform such operations on more-complicated symbolic expressions*

Represent and analyze mathematical situations and structures using algebraic symbols

Students should use symbolic algebra to represent and explain mathematical relationships

<i>Technology</i>	Radio Waves	DLN Connection	Waves
Standard 2: Core Concepts of Technology W: Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems	X	X	X
Standard 3: Relationships among technologies and the connections between technology and other fields J: Technological progress promotes the advancement of science and mathematics	X	X	X
Standard 17: Information and Communication Technologies A: Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information	X	X	X
E: There are many ways to communicate information, such as graphic and electronic means	X	X	X

Expected Student Behaviors

Standard 2 – Core Concepts of Technology

W: Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems – *Students should develop an understanding that systems thinking uses simulation and mathematical modeling to identify conflicting considerations before the entire system is developed.*

Standard 3 – Relationships Among Technologies and the Connections Between Technology and other Fields

J: Technological progress promotes the advancement of science and mathematics – *Students should understand that progress in science and mathematics leads to advances in technology, and visa versa.*

Standard 17 – Information and Communication Technologies

L: Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information – *Students should develop an understanding that the parts of the communication system are necessary if information is to be shared and understood by the sender and receiver.*

P: There are many ways to communicate information, such as graphic and electronic means *Students should understand that information can be communicated in various forms, such as graphic, digital, and multimedia.*



Expedition Videoconference Guidelines

Audience Guidelines

Teachers, please review the following points with your students prior to the event: Videoconference is a two-way event. Students and NASA presenters can see and hear one another.

Students are sometimes initially shy about responding to questions during a distance learning session. Explain to the students that this is an interactive medium and we encourage questions.

Students should speak in a loud, clear voice. If a microphone is placed in a central location instruct the students to walk up and speak into the microphone. Teacher(s) should moderate students' questions and answers.

Teacher Event Checklist

Date Completed	Pre-Conference Requirements
	Print a copy of the module.
	Have the students complete the pre-assessment.
	Email questions for the presenter. This will help focus the presentation on the groups' specific needs.
	Review the Audience Guidelines, which can be found in the previous section.
	Day of the Conference Requirements
	The students are encouraged to ask the NASA presenter qualifying questions about the Expedition.
	Follow up questions can be continued after the conference through e-mail.
	Post - Conference Requirements
	Have the students take the Post-Assessment to demonstrate their knowledge of the subject.
	Use the provided rubric as guidelines for content and presentation criteria.
	Teacher(s) and students fill out the event feedback.



Expedition Videoconference Outline

Introduction to Expedition Videoconference

Join the Digital Learning Network as we explore how astronauts on the International Space Station communicate using amateur, or HAM, Radio. Learn how amateur radio works, its purpose on the International Space Station, and how educators and students can participate in radio downlink events with astronauts through ARISS.

Outline for Video Conference

Welcome

Introduction

Define Amateur Radio

How HAM Radio Works

How World Uses Amateur Radio

How NASA uses Amateur Radio aboard ISS

How Educators and Students use Amateur Radio

How to Connect with the ISS

ARISS Connection Demonstration

Online Resources

Q&A

Good-Bye



Pre-Conference Requirements

Pre-Assessment

A week before the event, students will need to take the pre-conference assessment. This short assessment will provide useful background information for the presenters to prepare for the videoconference.

Pre-Conference Assessment Questions

1. What is sound?
2. How does sound travel?
3. List ways we can communicate with people on Earth.
4. List ways astronauts can communicate to Earth.
5. What is HAM radio?
6. Why is communication an important factor of NASA manned missions?
7. What is the electromagnetic spectrum?
8. Define radio wave.
9. What is a wavelength?
10. Heinrich Hertz is known for what? What is his legacy?

Suggested Answers to Pre and Post Assessment Questions:

1. What is sound?
Sound is vibration that passes through a solid, liquid, or gas. Certain frequencies of sound can be detected by the human ear.
2. How does sound travel?
Sound travels in waves.
3. List ways we can communicate with people on Earth.
Answers will vary.
4. List ways astronauts can communicate to Earth.
Radio and email are the most common forms of communication to the ground.
5. What is HAM radio?
HAM radio is another name for amateur radio. The word “ham” refer to the radio operators.
6. Why is communication an important factor of NASA manned missions?
Answers will vary.
7. What is the electromagnetic spectrum?
The electromagnetic spectrum is the range of all possible electromagnetic radiation (Students may include UV, infrared, visible, etc).
8. Define radio wave.
A radio wave is a electromagnetic wave occurring on the radio frequency portion of the electromagnetic spectrum.
9. What is a wavelength?
A wavelength is the distance between repeating units of a wave.
10. Heinrich Hertz is known for what? What is his connection to sound?
Hertz is known for his work on the electromagnetic theory of light. In honor of his work in the physics field, the SI unit for frequency is named Hertz.



Pre-Conference Activities

Article: Hamming It Up on the ISS

You see it on television: NASA officials contact astronauts on the Space Station through radio hookups. There's another way to keep in touch with crewmembers, though, and anyone with a ham radio system can participate.

Amateur radio, also called ham radio, has become the fun way for anyone to communicate with the Space Station astronauts. Anyone with a scanner can listen to the communications that take place between Earth and space, and if you have a transmitter, you can get in on the conversations.

"The whole point is to spark an interest in science and technology," says Frank Bauer, chief of the Guidance and Navigation Control Center at Goddard Space Flight Center in Maryland. "Communicating with ham radio started with the Space Shuttle program in 1983, and by the mid 80s, we had several school group interaction activities going.

"This opens new doors for access to the astronauts," Bauer says. "Before, only the president or other VIPs could talk with the astronauts while they were in space. Now with an amateur radio license, you can talk too. The ham radio project was the first effort to allow astronauts to talk with the general public."

To talk with the astronauts, you'll need to know several important bits of information, says Paul Dumbacher, a propulsion test engineer at Marshall Space Flight Center in Alabama, who also enjoys ham radio. Everything you'll need to know to get started is listed at the Amateur Radio on the International Space Station (ARISS) web site.

"The important things to know are when the Space Station will be over your location, what frequency the astronauts transmit on, and what the crew's schedule is," Dumbacher says. Information at the ARISS web site will tell you the call signs of the astronauts, so you'll know whom you're listening to, Dumbacher says. Taking the time to learn a bit of basic amateur radio lingo will help you understand the proceedings.

"Conversations begin with the sender's call signs and then a signal report," Dumbacher says. "Then someone is asked what their QTH is; that's short for your location. If an astronaut says, "QRZ," that means he's opening the conversation up for the next interested participant. It takes a while to learn the language of ham radio, but it's a wonderful opportunity to make contact with a piece of history. You can see NASA on TV, look at maps, and they don't seem real. But to go outside and look up and see the Space Station or hear them talking on the radio, that's real. To talk with people on a man-made object launched by a rocket is all very amazing."

While individuals can monitor Space Station transmissions from home, school groups can make it a class project and work closely with ham radio operators and NASA staff members to schedule a conversation with the astronauts. The ARISS project was started with that goal in mind.

"There are many options open to contacting the astronauts through amateur radio," Bauer says. "If schools can't contact the ISS from their location. They can use a program called Tele-bridge, which is a phone bridge set up to communicate from telephone to short wave radio. We've had groups in Australia and South Africa use Tele-bridge to make their connections."

It's a challenge to be sure the school group is ready to communicate at the precise moment the Space Station is overhead, Bauer says. The equipment can't be too simple or too complex, you have to have the orbit information right. The children have to be prepared to conduct their conversations efficiently. But it's all worth it when it works."

The actual contact with the astronauts is the top of the pyramid, Bauer says. It's the peak experience. "But the foundation under that pyramid peak is the remarkable part. The learning required to prepare for this contact-antenna, radio, orbit, press releases, geography, trial and error-it all shows the children how demanding this process is, and how much knowledge is required for success."

It's a living example of why mathematics and science are good things. "It shows practical use of formulas," Dumbacher says. "Students learn about complex ideas like Doppler Shift and trajectory paths. It shows that even addition and subtraction get you to important points. Science matters; without science we wouldn't have ISS; we wouldn't understand weather, we wouldn't understand basic functions of everyday life. And there's no better way to learn it than by doing it."

If you get the opportunity to make contact with Shuttle or Space Station astronauts, Dumbacher has one bit of advice. "Be sure to get a QSL card. That's a card NASA will send you proving that you talked to an astronaut. There's information about getting it on the ARISS web site. You'll want to be able to put that up on your bulletin board and tell everyone."

Courtesy of NASA's Space Operations Mission Directorate

Radio Waves

Teacher Sheet(s)

Objective: Students will draw an electromagnetic spectrum and calculate frequency and wavelength.

Level: 9-12

Subjects(s): Physical Science, Physics, Mathematics, Technology

Prep Time: Less than 10 minutes

Duration: 40 minutes

Materials Category: Common Household

National Education Standards

Science: Unifying Concepts, Physical Science

Math: Algebra

Technology (ITEA): 2, 3, 17

Materials:

(Per group)

- Paper
- Pencil
- Calculator

Pre-Lesson Instructions:

None

Background Information:

None

Guidelines:

1. Read the article, "Hamming It Up On ISS." Discuss the use of amateur radios and how they are being used to communicate to astronauts.

2. Explain the following:

MF - medium frequency between 300 to 3000 kHz

HF - high frequency between 3000 and 30,000 kHz

VHF - very high frequency between 30 and 300 MHz

UHF - ultrahigh frequency between 3×10^8 Hz and 3×10^9 Hz

3. Review equations:

$$\lambda = v/f$$

$$T = 1/f$$

$$v = d/t$$

4. An electromagnetic spectrum has been provided as a reference. You may wish to share this with the students for the student procedure section.

Discussion/Wrap-up:

None

Extensions:

1. 104.3 MHz FM
68 KHz AM
98.1 KHz AM
2. Change MHz to Hz — $99.5 \text{ MHz} = 99.5 \times 10^6 \text{ Hz}$
 $\lambda = v/f = (3.0 \times 10^8 \text{ m/s})/(99.5 \times 10^6 \text{ Hz}) = 3.02 \text{ m}$
3. AM radio waves have longer wavelengths than FM radio waves. AM waves can bend around hills and buildings. The shorter wavelength FM radio waves are blocked by large objects.
4.
 - a. $T = 1/f$
 $0\text{s} = 1/f$
 $2 \text{ m/s} = f$
 - b. 165
5. $T = 1/f$
 $= 1/242 \text{ Hz}$
 $= .00413223 \text{ s} = 4.13 \text{ ms}$
6.
 - a. $v = d/t$
 $(450\text{m})/(2.5\text{s}) = 180\text{m/s}$
 - b. $T = 1/f$
 $1/520 \text{ Hz} = .001923\text{s} = 1.92 \text{ ms}$
 - c. $\lambda = v/f$
 $(180 \text{ m/s})/(520 \text{ Hz}) = 0.3462 \text{ m}$
7. AM means amplitude modulation.
8. FM means frequency modulation.
9. Modulation means the process of impressing information (code, speech, video, data, etc.) on to a higher frequency carrier.

Radio Waves

Student Sheet(s)

Objective:

Students will draw an electromagnetic spectrum and calculate frequency and wavelength.

Materials:

- Paper
- Pencil
- Calculator

Background:

The waves in the electromagnetic spectrum that have the lowest frequencies and longest wavelengths are called radio waves. Radio waves are produced when charged particles move back and forth in antennas. Waves coming out of the radio are sound waves. These are different than radio waves. Radio waves are the waves used to transmit information from the antenna of a broadcasting station to the antenna on your radio or television.

AM radio stations broadcast on frequencies between 535 kilohertz and 1605 kilohertz. FM radio stations broadcast on frequencies between 88.1 megahertz and 107.9 megahertz. Because FM radio waves are shorter, they don't diffract as much around buildings, and aren't received as well as AM radio waves, particularly in mountain regions or canyons. This is why many localities have poor FM reception, while AM reception comes in loud and clear.

AM stands for amplitude modulation. In this method, the information is put into a radio wave by varying the amplitude. For example, if all we wanted to do was send 1s and 0s, we could have just two different levels of amplitude that correspond to these numbers—1 being high, 0 being low.

FM stands for frequency modulation. This time the amplitude is kept constant; it is the frequency that is varied.

Ham radios send and receive radio transmissions. Ham radios use electricity to operate, however, many can also run on batteries. When terrible storms devastate communities, ham radios are sometimes the only communication in and out of the affected area.

Procedure:

1. Draw a chart of the electromagnetic spectrum covering 100 kilohertz to 1000 megahertz.
2. Label the MF, HF, VHF, and UHF portions of the spectrum on your chart.
3. Locate on your chart at least eight radio services such as your favorite AM and FM commercial broadcast stations, CB, television, and amateur radio.
4. Using the formula, find the length of the radio waves of five of the items you listed on the chart.

$$\lambda = v/f$$

Questions:

1. Identify the following as AM or FM stations based on the frequency:

104.3 MHz	
68 KHz	
98.1 KHz	

2. A radio wave has a frequency of 99.5 MHz. What is its wavelength?
3. AM radio signals have wavelengths between 600 meters and 200 meters, while FM signals have wavelengths about 3 meters. Explain why AM signals can often be heard behind hills while FM signals cannot.
4. A sound wave has a wavelength of 0.80 meters and a velocity of 335 m/s is produced for 0.70 seconds.
 - a. What is the frequency of the wave?
 - b. How many complete waves are emitted in this time interval?

5. A sound wave has a frequency of 242 hertz. What is the time between successive wave crests?
6. A sound wave produced by a wild animal 450 meters away is heard 2.5 seconds later.
 - a. What is the speed of sound in the air?
 - b. The sound wave has a frequency of 520 Hz. What is its period?
 - c. What is its wavelength?
7. What does AM stand for?
8. What does FM stand for?
9. What does modulation mean?



Post-Conference Activities

Online Post-Assessment

After the event students will need to take the post-conference assessment. (These questions are the same questions used in the pre-assessment.) The short assessment will help us measure student learning and identify any changes that need to be made in future programs.

Post-Conference Assessment Questions Grades 9-12

1. What is sound?
2. How does sound travel?
3. List ways we can communicate with people on Earth.
4. List ways astronauts can communicate to Earth.
5. What is HAM radio?
6. Why is communication an important factor of NASA manned missions?
7. What is the electromagnetic spectrum?
8. Define radio wave.
9. What is a wavelength?
10. Heinrich Hertz is known for what? What is his legacy?

Waves

Teacher Sheet(s)

Objective: Students will identify the components of a radio wave and create waves in different frequencies.

Level: 9-12

Subjects(s): Physical Science, Technology

Prep Time: 10-30 minutes

Duration: 40 minutes

Materials Category: General Classroom

National Education Standards

Science: Unifying Concepts, Physical Science

Technology (ITEA): 2, 3, 17

Materials:

(Per group)

- Glass, plastic, or metal pan
- Watero Eye dropper
- One Slinky per group of two; or
- One short rope or jump rope
- Data collection sheet

Pre-Lesson Instructions:

None

Background Information:

Transverse waves cause the particles of a medium to move perpendicular to the direction of the wave. In a Slinky, the spring is displaced up and down at right angles to the motion of the wave. Waves in piano and guitar strings are examples of transverse waves. A longitudinal wave causes the particles of a medium to move parallel to the direction of the wave. The displacement of the spring is parallel to the motion of the wave. A sound wave is an example of a longitudinal wave. Fluids- either liquids or gases-transmit only longitudinal waves.

Guidelines:

1. Read the article, "Hamming It Up On ISS." Discuss the use of amateur radios and how they are being used to communicate to astronauts.
2. After dropping water in the pan, guide students to observe the wave that has been created as it moves outward along the surface of the water in expanding circles.

3. Explain how the Slinky represents waves and how students might look at different frequencies. Guide students to understand that faster movement corresponds to higher frequency and shorter wavelengths.
4. Show a chart of the electromagnetic spectrum. Discuss the different forms of waves contained in the spectrum. Discuss the size of the wavelengths and the energy of each type of wave.

Discussion/Wrap-up:

None

Extensions:

- Have interested students contact a local ham radio operator or local amateur radio club to learn more.
- Invite a ham radio operator to speak to your class and provide a demonstration.

Waves

Student Sheet(s)

Objective:

Students will identify the components of a radio wave and create waves in different frequencies.

Materials:

- Glass, plastic, or metal pan
- Water
- Eye dropper
- One Slinky per group of two; or
- One short rope or jump rope
- Data collection sheet

Background Information:

When Heinrich Hertz first demonstrated radio waves in 1886, he found the source of all waves was something that vibrates. Radio waves vibrate at the lowest frequency and have the longest wavelengths on the electromagnetic spectrum. Radio waves are electromagnetic waves that originate from the vibration of electrons. Sound waves are not electromagnetic waves, but a mechanical vibration of matter. So even though we hear a radio by means of sound waves, radio waves and sound waves are not the same.

Electromagnetic waves are classified according to their frequency. Waves all move, or vibrate, at the same speed ("c" for constant), but differ in their frequency. The frequency is how often a vibration occurs. This unit of frequency is called a hertz (Hz). Thus, the speed of a given wave is measured in meters per second.

A wavelength is the distance, measured in meters; a wave travels through space in a single cycle. It can be measured from any point along the wave as long as it is consistently measured from the same point. The speed of the wave is equal to the frequency times the wavelength. The amplitude of a wave is the maximum displacement on either side of the midpoint of a wave. The midpoint is the point at which the wave is at rest.

A specific radio frequency is assigned to amateur radio operators when they are transmitting to space. All amateur radio operators, this includes those who operate for Space Amateur Radio Experiments (SAREX) missions, use a small portion of the frequency bands on the electromagnetic spectrum. Any amateur station that is located more than 50km above Earth's surface is defined by the Federal Communications Commission (FCC) as a space station. Amateur satellites, the Space Shuttle orbiters, the Russian MIR Space Station, and the International Space Station all fall under this category.

Procedure:

1. Predict what will happen when a drop of water is dropped into a pan of water, where the surface of the water is flat. Write predication on the data collection sheet.
2. Drop water from an eyedropper into the center of the pan. Write down your observations. What shapes were the waves that were created? How did the waves move? Were the circles evenly spaced?
3. Draw a picture of the wave. Label the crest, trough, amplitude, midpoint, and wavelength.
4. Stretch the Slinky to about 1 meter on the floor (not carpet) or tabletop. (Do not overstretch.)
5. One student holds one end of the Slinky still.
6. Another student will move the other end slowly back and forth. Start slowly then increase the rate at which the Slinky is moved back and forth.
7. This time you and your lab partner will create equal-sized pulses at the same time from opposite ends of the Slinky. It may require some practice to get your timing synchronized. Try it both ways-that is, with pulses on the same side and then with the pulses on opposite sides of the line of propagation. Pay special attention to what happens as the pulses overlap. Record your observations.

Data Collection Sheet

Name _____

Group Names _____

Date _____

1. Predict: what will happen when a drop of water is dropped into the pan of water?

2. Draw observations.



3. Written observations of Slinky

4. Draw a picture of a wave and label.



5. Describe observations of equal-sized pulses.
6. Distinguish among the wavelength, frequency, and period of a wave.
7. What is the amplitude of a wave, and what does it measure?
8. What is the midpoint?
9. If you want to increase the wavelength of waves in a rope, should you shake it at a higher or lower frequency?
10. Distinguish between a mechanical wave and an electromagnetic wave.
11. When a wave crosses a boundary between thin and thick rope tied together, its wavelength and velocity change, but its frequency does not. Explain why the frequency is constant.
12. In step six, is the Slinky producing a transverse or longitudinal wave?
13. What did you learn from this activity?



NASA Education Evaluation Information System (NEEIS)

Please complete an online evaluation form to provide feedback on the NASA Challenge.

Feedback from you and a few of your students would be appreciated.

<http://dln.nasa.gov/dln/content/feedback/>

National Aeronautics and Space Administration



NASA Digital Learning Network

presents

Certificate of Completion

to

for

HAM It Up!

Instructor

Date



Vocabulary

Amplitude Modulation (AM): a technique used in electronic communication, most commonly for transmitting information via a radio carrier wave; works by varying the strength of the transmitted signal in relation to the information being sent.

ARISS: acronym for Amateur Radio on the International Space Station; a volunteer program which inspires students, worldwide, to pursue careers in science, technology, engineering and math through amateur radio communications opportunities with the International Space Station (ISS) on-orbit crew.

Electromagnetic Spectrum: the range of all possible electromagnetic radiation; the "electromagnetic spectrum" (usually just spectrum) of an object is the characteristic distribution of electromagnetic radiation from that object.

Energy: strength or power to work or be active; force; vigor; the power of certain forces of nature to do work.

Frequency: a measure of the number of occurrences of a repeating event per unit time.

Frequency Modulation (FM): a technique used in telecommunications; conveys information over a carrier wave by varying its frequency.

HAM Radio: also known as amateur radio

Hertz: the SI unit for measuring frequency; named in honor of physicist Heinrich Hertz.

International Space Station: a laboratory orbiting the Earth; a joint mission with the space programs of 16 countries, including the United States.

Radio Waves: electromagnetic waves occurring on the radio frequency portion of the electromagnetic spectrum.

Sound Waves: the vibration transmitted through a solid, liquid, or gas; particularly, sound means those vibrations composed of frequencies capable of being detected by ears.

Wavelength: a measure of a light; the peak to peak distance one vibration of an electromagnetic wave



Resources

NASA

For information on exploratory missions, manned spaceflight, and more, please visit this website.

www.nasa.gov

American Radio Relay League (ARRL)

<http://www.arrl.org>

Radio Amateur Satellite Corporation (AMSAT)

<http://www.amsat.org>



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